Check-Mate?

Origin of the ionization rate excess in the Galactic Centre.

AIM

The ionization rate in the Galactic Centre Region (GCR) is 3-4 orders of magnitude higher than the Spitzer value ($10^{-17}\ s^{-1}$) measured in the local interstellar medium (ISM). This excess is not measured in the gamma-ray counterpart. We study the plausibility of the different CR ionization scenarios to explain this excess.

INTRODUCTION

We consider hadronic (h) and leptonic (l) CR processes. The products of CR interactions with the ISM at different energies are a probe of the CR intensity at different regions of the Galaxy. We use gamma-ray data of the GCR to constrain the high-energy CR (HECR) spectra and derive the necessary LECR spectra to reach the high ionization rate of $2 \times 10^{-14} s^{-1}$.

Ionization

$CR + H_2 \rightarrow CR + H_2^+ + e^-$

$H_2 + H_2^+ \rightarrow H_3^+ + H$

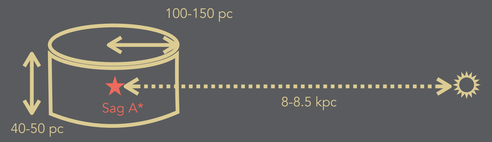
Gamma-ray emission

Pion production (h)

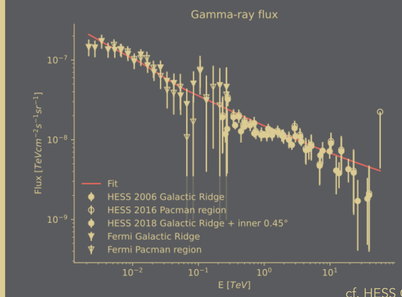
Inverse Compton scattering (l)

Relativistic Bremsstrahlung (l)

The Galactic Centre region we consider :



IONIZATION BY CR PROTONS



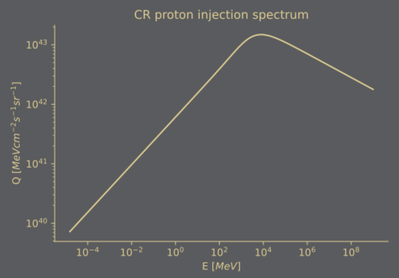
The gamma-ray data of the GCR is best fit by this HECR proton spectrum: $J(p) \propto p^{-4.5}$

Neglecting losses in the HE, this gives an injection spectrum for the HECR: $Q(p) \propto p^{-4.2}$

cf. HESS Collaboration, 2006, 2016 & 2018; cf. Gaggero et al., 2017; cf. Kafexhiu et al., 2014

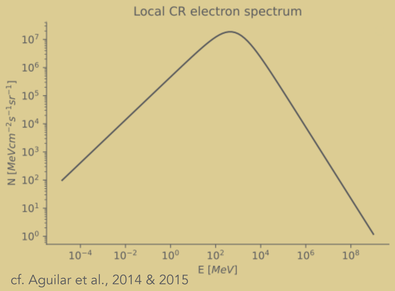
A first approximation of the LECR proton spectrum can be obtained by extrapolating the required injection in HE and considering only energy losses:

$$N(E) = \frac{1}{\dot{E}} \int Q(E)\, dE$$

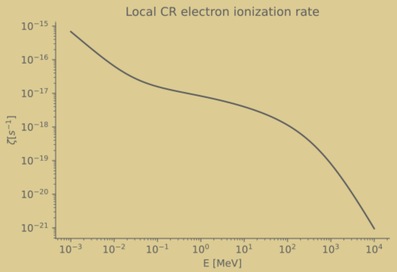


IONIZATION BY CR ELECTRONS

Because there are no available constraints on leptonic gamma-ray emissions in the GCR, a slightly different approach is adopted here. The local CR electron spectrum is known: $J(E) \propto E^{-1.236}$



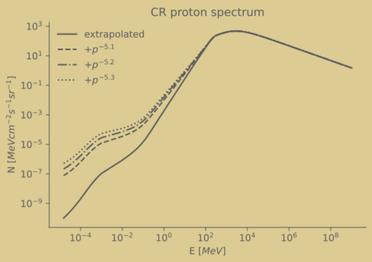
cf. Aguilar et al., 2014 & 2015



This spectrum already gives a higher ionization rate than the Spitzer value ($10^{-17} s^{-1}$) and almost as high as the GCR value ($10^{-14} s^{-1}$).

CONCLUSION

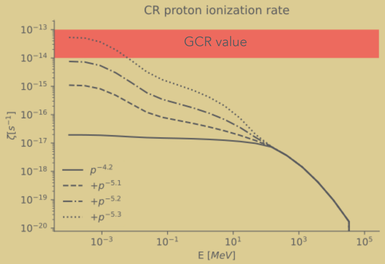
The high ionization rate observed in the Galactic Centre must not be from cosmic rays as the most optimistic scenarios can't be sustained energetically. Even if they were, they are many orders of magnitude higher than the photon luminosity of the supermassive black hole but have never been observed. The leptonic contribution needs to be studied in more detail. Another promising scenario is the photoionization of the ISM in the GCR.



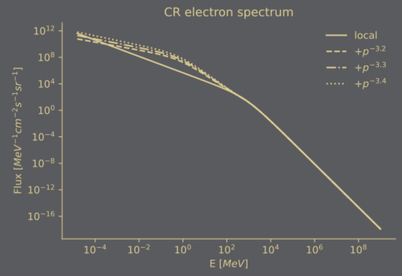
The injection spectrum in the LE is enhanced with a power-law until obtaining the GCR ionization rate. The enhancements are $p^{-4.2}, p^{-5.1}, p^{-5.2}$ and $p^{-5.3}$.

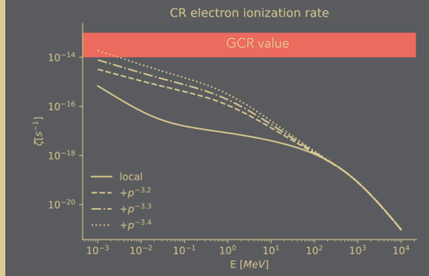
An enhancement of $p^{-5.3}$ of the LECR proton spectrum down to 100 keV can produce the GCR ionization rate.

But these low energies are described by the Maxwellian distribution and are hard to be constrained. Moreover to maintain an enhancement of $p^{-5.3}$, a CR injection power of 10^{40} ergs/s is needed, which is several orders of magnitude above the black-hole photon luminosity.



The electron spectrum is enhanced in LE until obtaining a GCR ionization rate. The enhancements are $p^{-3.2}, p^{-3.3}$ and $p^{-3.4}$





An enhancement of $p^{-3.4}$ of the LECR electron spectrum down to 1 keV can produce the GCR ionization rate. But again, these energies are too low to be constrained by a power-law. Moreover, CR electrons are much less in number than CR protons which is also why despite a high electron ionization rate, even the local value stays much lower.

CONTACT

Sruthiranjani RAVIKULARAMAN
PhD student
Université Paris Cité, CNRS, AstroParticule et Cosmologie,
F-75013 Paris, France

ravikularaman@apc.in2p3.fr

Université Paris Cité